
	ITTC – Recommended Procedures		7.5 – 02 07 – 02.6 Page 1 of 6
	Testing and Extrapolation Methods Loads and Responses, Sea Keeping Model Tests on Damage Stability		Effective Date 2002

CONTENTS

- 1 PURPOSE**
- 2 PARAMETERS**
 - 2.1 General Considerations**
 - 2.2 Special Requirements for Ro-Ro Ferries:**
- 3 DESCRIPTION OF PROCEDURE**
 - 3.1 Model Design and Construction**
 - 3.2 Instrumentation**
 - 3.3 Preparation**
 - 3.4 Execution of Tests**
 - 3.5 Report**
- 4 VALIDATION**

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 INTERNATIONAL TOWING TANK CONFERENCE	ITTC – Recommended Procedures	7.5 – 02 07 – 02.6 Page 2 of 6	
	Testing and Extrapolation Methods Loads and Responses, Sea Keeping Model Tests on Damage Stability	Effective Date 2002	Revision 01

Model Tests on Damage Stability

1 PURPOSE

The procedure for these tests is for carrying out experiments on a flooded ship model in waves to determine the significant wave height that will cause the model to capsize.

It is based on a review of the most recent model experiments on damage stability of Ro-Ro passenger ships and is meant to apply to the general case of beam seas damage at zero forward speed. However, the general principles should apply to any ship type and it can be modified or extended for special studies.

2 PARAMETERS



2.1 General Considerations

It is assumed that during the tests the model is already damaged, flooded and stationary at the start of the experiment. The procedure does not consider modelling the transition from an intact hull to a damaged hull, when the ship is initially travelling with non-zero forward speed.


In general, model experiments will be carried out in conditions corresponding to the worst damage scenario. It is assumed that the parts of the hull and superstructure damaged during the collision have been removed from the ship. Therefore the edges of the damage are sharp.

In the case of Ro-Ro ferries, the models will be tested with the car deck empty, until more information is available concerning the flow around vehicles on the car deck. Also, it is assumed that the cargo has not shifted during the collision, or at any other time.

Damaged stability model experiments for design evaluation must be carried out in irregular waves. It has been observed that flooding and drainage patterns in regular waves are unrealistic compared to irregular waves.

2.2 Special Requirements for Ro-Ro Ferries

Resolution 14 of the 1995 SOLAS conference includes an option that an Administration may, as an alternative to calculation of the damage stability properties of a ship in waves, accept model tests carried out for an individual ship in accordance with a model test method developed by IMO, justifying that the ship will not capsize in an irregular seaway. This model test procedure is specified by the IMO. In the case of Ro-Ro ferries, the ITTC procedure and associated guidelines are intended to supplement the IMO method with a technical explanation for the adopted methodology. They are not an alternative, and any experiments carried out under Resolution 14 must satisfy all of the Administration's requirements, regardless of the recommended ITTC procedure and guidelines.



	ITTC – Recommended Procedures	7.5 – 02 07 – 02.6 Page 3 of 6	
	Testing and Extrapolation Methods Loads and Responses, Sea Keeping Model Tests on Damage Stability	Effective Date 2002	Revision 01

3 DESCRIPTION OF PROCEDURE

3.1 Model Design and Construction

The model should be constructed to a high accuracy, with adequate strength and stiffness properties. Special care should be taken to ensure that the model is free from leaks. It is recommended that stiffness and flooding characteristics are tested and corrected prior to the start of any experiments.

Minimum model scale should be 1:40. In no case should the overall length of the model be less than 3.0 metres. However, based on the reported experience of ITTC member organisations with respect to proper modelling of internal arrangements and fittings, it is recommended to consider a minimum size for the model of 4.0 metres.

 The model should be an accurate representation of the hull up to the main deck, with the correct sheer and camber on the deck. The hull should be divided into compartments by watertight bulkheads. The floodable compartments and all pertinent features influencing the flooding process should be geometrically similar, in terms of flooded volume and free surface areas, to those of the ship. The wall thickness by way of the flooded spaces should not exceed 4 mm. Care should be taken to build cross-flooding arrangements and other small diameter ducts  quately sized (a minimum cross sectional area of 500 mm² is recommended) to allow for realistic flow of water or air. Special devices, such as deck drains, should be scaled geometrically unless this results in dimensions being too small so that viscous effects are significant.


Where appropriate compartments should be properly vented to prohibit air trapping which would induce undesirable effects. It is recommended to fit transparent decks and bulkheads, to allow flooding to be observed and leakages identified.

The external geometry of the ship superstructure above the bulkhead (freeboard) deck should be modelled up to the point where it no longer influences model behaviour or the flooding process (heel angle of at least 30 degrees). In the case of a Ro-Ro ferry, where the superstructure is significant, it is necessary to model the external superstructure up to the third deck above the bulkhead deck. The same considerations as with the main hull apply to internal arrangements and fittings.

Any appendages likely to have an effect on roll motion, such as bilge keels, skegs, fin stabilizers, and rudders should be fitted.

For modelling a disabled ship, the damage hole shall have a trapezoidal shape, with a 15 degree slope from the waterline, so that the top of the opening is wider than the bottom. The width of the damage at the main deck should be at least that required by the SOLAS regulation II-1/8.4.1. The main deck shall have a cut-out in the shape of an isosceles triangle, with a height equal to B/5.

Surface and volume permeabilities of floodable spaces should be modelled correctly according to full scale. This can be accomplished by including foam blocks representative of major objects in the compartment. If no information is available for a specific non Ro-Ro vessel, the following values for volume permeability should be used:

 INTERNATIONAL TOWING TANK CONFERENCE	ITTC – Recommended Procedures	7.5 – 02 07 – 02.6 Page 4 of 6	
	Testing and Extrapolation Methods Loads and Responses, Sea Keeping Model Tests on Damage Stability	Effective Date 2002	Revision 01

Void spaces	100%
Passenger or accommodation spaces	80%
Engine room	70%
Machinery spaces	70%

Member organisations with experience in model testing of damage stability for Ro-Ro passenger vessels use SOLAS-defined permeabilities adjusted to reflect the model construction and procedure described herein as follows:

Void spaces	98%
Passenger or accommodation spaces	98%
Engine room/Machinery spaces	85%
Store rooms	60%

3.2 Instrumentation

The instrumentation system should be appropriate to the model and type of test carried out. The use of non-contact measurement systems is recommended when feasible. If it became necessary to attach cables to the model care should be taken to minimise interference between cables and model. The instrumentation should guarantee the measurement of all the pertinent parameters.

- wave elevation,
- model attitude and motion in 6 DOF,
- relative motion between deck and wave surface at damage opening,
- height of water in each flooded compartment

All data should be stored as synchronised time histories, at a minimum sampling frequency of ≥ 100 Hz. Video records of the experi-

ments are also extremely useful for interpreting the results.

Sensors should be calibrated according to ISO 9001 standards or equivalent. Any systems, which rely on data from combined signals, such as integration of depth of water on deck from point measurements, must be checked with known loads in static and dynamic scenarios.


3.3 Preparation

The fully instrumented model must be checked for its mass distribution properties in the intact and damaged conditions.

In both intact and damaged conditions, the model should satisfy the correct displacement and draught marks (T_A , T_M , T_F , port and stb.) with a maximum tolerance in any one draught mark of ± 2 mm. Draught marks forward and aft shall be located as near FP and AP as practicable.

The radii of gyration for pitch, yaw and roll (in air) should correspond to the equivalent values for the ship. In the absence of more accurate knowledge a value of $0.40B$ should be adopted for the roll radius of gyration and $0.25L$ for both the pitch and yaw radii of gyration.

These values could be checked by swinging the model in the air, in a manner similar to that used for sea keeping experiments. The vertical position of the centre of gravity should be correct, and should be checked for the intact model by an inclining test or equivalent. A

	ITTC – Recommended Procedures	7.5 – 02 07 – 02.6 Page 5 of 6	
	Testing and Extrapolation Methods Loads and Responses, Sea Keeping Model Tests on Damage Stability	Effective Date 2002	Revision 01

maximum tolerance on the measured GM of -2 mm in model scale is recommended.

The natural roll period of the intact and damaged model should be determined from a roll decay test. This should be done in an area where reflected waves do not influence the results. Care should be taken with the damaged model not to flood the main deck during this test if the residual freeboard is low. It is also desirable to carry out an inclining test for the flooded model. This, however, can be difficult, if the model has inherently low stability or a very low freeboard after flooding. It is desirable to check the large angle stability of the model against the calculated values, at least up to the point of maximum righting moment.

3.4 Execution of Tests

There should be a clearance of at least 1 metre between each end of the model and the tank wall, when the model is placed across the tank, normal to the direction of the waves. The water depth in the tank should also be properly modelled.

It is desirable to include estimated additional heeling moments that are likely to be present in an emergency situation. These can be caused by mean wind forces, passengers gathered at the edge of the deck, lifeboat launching etc. For tests with Ro-Ro ferries, it is recommended that the model be ballasted to achieve 1 degree heel towards the damage side for practical purposes.


The flooded model is positioned in the tank, approximately 15 metres away from the wavemaker(s). If this is not practical the model

should be far enough from the wavemaker(s) to avoid breaking wave transients, which occur in the vicinity of the wavemaker. Prior to starting each experiment, the draft, trim and heel of the model should be checked. It is particularly important to make sure that there is no water in the intact compartments at the start of a test. Data collection should start in calm water, before the waves reach the model. This provides a datum level for each signal.

The model should be allowed to drift under the action of the waves and should remain free from restraints at all times during the testing. If necessary, guide ropes can be fitted to the model on the centreline at the stem and stern, in a symmetrical fashion and at a vertical height between the damaged waterline and the vertical centre of gravity. These lines are kept slack except for short times when they can be used to keep the model on course, and then released again. However, if the model has a natural tendency to drift at a steady angle, this should not be corrected.

Wave signals should be random for a minimum period equivalent to at least 30 minutes in full-scale (based on Froude scaling). At least 10 experiments should be carried out in irregular waves. The test period for each experiment should be of duration such that a stationary state has been reached, but not less than 30 minutes in full-scale. A different wave realisation train should be used for each experiment.

Wave spectra should be measured at three locations along the length of the tank, spanning the drift range of the model. The first measurement should be close to the model at the start of the experiment, at the wavemaker end

	ITTC – Recommended Procedures	7.5 – 02 07 – 02.6 Page 6 of 6	
	Testing and Extrapolation Methods Loads and Responses, Sea Keeping Model Tests on Damage Stability	Effective Date 2002	Revision 01

of the tank, the second at the mid-point of the tank, and the third close to the beach end of the tank. Variation in $H_{1/3}$ between nominal and measured spectra should be within $\pm 5\%$ at each location and variation in T_p should be within $\pm 5\%$. Moreover, deriving from ocean wave measurements, a maximum significant wave height of $H_{1/3}=(gT_p^2/(2\lambda))=0.05$ is recommended and in the absence of information on specific spectrum data, JONSWAP type spectra should be used. Wave spectra used during the tests must be reported and matched with the nominal values over the full repeat period.

The effect of wind pressure on the model may be taken into account by using a fan system attached to the carriage or tank. Current need not be modelled.

3.5 Report

The report of the results should include, as a minimum, the measured wave spectra and statistics ($H_{1/3}$, T_p) of the wave elevation at the 3 different locations in the basin for a representative realisation. Analysis of the time series



should include records of wave elevation, model attitude and motion in 6 DOF, relative motion between deck and wave surface at damage opening, height of water in each flooded compartment and of the drift speed.

4 VALIDATION

All data measurement should conform to the recommendations of the relevant ITTC Procedures regarding uncertainty analysis.

The model tested should be considered as surviving if a stationary state is reached for the recommended 10 successive test runs.

The model tested should be considered as capsized (a) when the maximum roll angle exceeds 30° against the vertical axis or (b) when the mean roll angle exceeds 20° , averaged over a period of at least 3 minutes full scale. As these angles relate to the launching of life boats in merchant ships, different limits should be considered for naval vessels which are subject to different stability standards.